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IN THE

Supreme Court of the United States

OCTOBER TERM, 1971

No. 71- 503

RICHARD T. WHITCOMB, *Petitioner,*

v.

GENERAL DYNAMICS CORPORATION AND AMERICAN AIRLINES, INC., *Respondents.*

APPENDIX TO PETITION FOR WRIT OF CERTIORARI TO THE UNITED STATES COURT OF APPEALS FOR THE FOURTH CIRCUIT

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APPENDIX

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF VIRGINIA
NEWPORT NEWS DIVISION

CIVIL ACTION No. 1174

RICHARD T. WHITCOMB, *Plaintiff*,

v.

AMERICAN AIRLINES, INC., *Defendant*.

and

CIVIL ACTION No. 1133

GENERAL DYNAMICS CORPORATION, *Plaintiff*,

v.

RICHARD T. WHITCOMB, *Defendant*.

Memorandum

Before even attempting the unwinding of this complicated combination of patent law and aerodynamics, the record is to reflect the gratitude of this Court to the very, very competent attorneys, Carl G. Love, Esquire, for the plaintiff, and Davidson C. Miller, Esquire, for the defendant. To try this long case before a judge, admittedly a novice in patent litigation and transonic aerodynamics, has posed a problem to these gentlemen of the bar which they have overcome graciously with great patience. While the conclusion of the matter has thus not been made easy in resolution, it, nevertheless, has been an orderly accomplishment.

The controversy in litigation arises over the use of General Dynamics of certain bodies attached to the wings of its Convair 990 and 990A aircraft, variously designated as "anti-shock bodies" or "speed capsules." These aircraft, with the anti-shock bodies on the wings thereof, were pur-

chased and operated by American Airlines as the "990 Astrojet."

Whitcomb claims, and General Dynamics and American Airlines deny, that the 990 aircraft with such anti-shock bodies constitute infringement of a patent held by Whitcomb. In addition to denying infringement, General Dynamics and American Airlines also assert that the patent, for various reasons, is invalid.

Suffering, perhaps, in the brevity of this description, the invention may be described as a cylindrical body, pointed at either end, attached to the upper surface of the wing of a transport type aircraft, in a position parallel to the fuselage, which attachment, when the aircraft is traveling at high subsonic speeds, just below the speed of sound, will serve as a means to control boundary layer separation, with the practical effect of increasing the speed of the aircraft—in this case, 10-12 knots.

It is alleged that by the addition of the Whitcomb invention, General Dynamics was able to meet the speed requisite required in its contract with American Airlines and to thus perfect the sale of a number of 990 aircraft.

Richard T. Whitcomb instituted his civil action against American Airlines, Inc. for patent infringement in the Alexandria Division of this District. About the same time, General Dynamics Corporation filed its suit against Richard T. Whitcomb for declaratory judgment that the patent was invalid and had not been infringed, in the Newport News Division of this District. In the latter suit Whitcomb proceeded by counterclaim for patent infringement against General Dynamics.

Because of the common questions of law and fact involved, the parties agreed, and the Court concurred, that the Alexandria action should be transferred to the Newport

News Division. Following transfer, upon motion of Whitcomb, the cases were consolidated for trial. For the consolidated trial, the parties aligned themselves so that Whitcomb proceeded as plaintiff and General Dynamics and American Airlines, Inc. jointly proceeded as defendants. In fact, the defense was conducted by General Dynamics, which, pursuant to the purchase agreement for the 990 aircraft, had agreed to indemnify American Airlines, Inc. for liability, if any, arising from patent infringement.

FINDINGS OF FACT

1. U.S. Letters Patent No. 2,967,030 were granted to Richard T. Whitcomb under 35 U.S.C. § 266 on January 3, 1961, maturing from an application filed on November 13, 1957. Since January 3, 1961, Whitcomb has remained the sole owner of this patent in suit. The claims of the patent in issue in this action are claims 1, 2 and 3, which Whitcomb asserts have been infringed by the manufacture, use and sale of the Convair 990 and 990A aircraft built by General Dynamics.

2. As the speed of an airplane in relation to the atmosphere increases toward the speed of sound, certain physical phenomena begin to occur at high subsonic speeds, in excess of about Mach 0.8. The air passing over the upper surface of the wing, because it is accelerated, moves over the wing at a speed faster than the speed of the airplane itself. Thus, as the airplane flies at high subsonic speeds, just under the speed of sound, the air passing over the top of a cambered wing accelerates to a speed equal to or exceeding the speed of sound. At this point, a portion of the airflow over the curved wing enters a supersonic phase, while another portion remains subsonic. This condition of partial subsonic and partial supersonic flow is known in aerodynamics as "transonic flow."

3. A the point where the local air velocities over the wing increase to supersonic velocity, a sharp pressure change occurs and this pressure change is known both to the laymen and the aerodynamicists as a shock wave. Because of the camber or curvature of the upper surface of the wing, the sharp pressure change or shock wave, occurs just rearward of the region of maximum thickness of the wing. Behind or rearward of the shock wave, which clings to the top of the wing, the flow of air undergoes violent changes: from the smooth laminar flow forward of the shock wave, the flow behind the shock wave loses energy, and changes direction, even to the point that it may begin to flow forward, rather than rearward. This results in the condition known to the aerodynamicists as "boundary layer separation", where the air flow, under the influence of the sharp pressure changes, moves away from, or separates from, the wing surface.

4. The compressibility drag induced by boundary layer separation is severe and results, when it occurs in the higher subsonic speeds, in a sharp increase in the total drag of the airplane. This increase, in fact, is so rapid and of such magnitude that, as a practical matter, the drag more than offsets the thrust of the engines and prohibits the airplane from increasing its speed any further. In fact, the evidence indicates that the drag rise for a conventional jet aircraft rises so abruptly that even substantial increases in the airplane forward thrust would not result in any appreciable speed increase. In other words, the drag rise curve for a particular airplane is virtually a speed barrier through which the airplane may not pass.

5. Prior to 1957, it was well accepted among aerodynamicists that the addition of structure to an aircraft would result in an increase in the drag of the airplane in subsonic flight. That is, while a wing alone would add some drag, a wing and fuselage combination would add more drag, and the addition of the empennage would add

more drag, the addition of engines would add more drag, the addition of supporting struts for the engines would add yet more drag, i.e., the drag would be increased measurably by the addition of an additional body. Dr. Whitcomb's invention, to some degree, is a contradiction to the absolutes of this theory.

The Whitcomb invention, the patent, and proceedings thereon.

6. The patentee and plaintiff herein, Richard T. Whitcomb, is and has been since 1943 an aerodynamicist in the employ of the National Advisory Committee for Aeronautics and, since the title was changed in 1958, of the National Aeronautics and Space Administration, at the Langley Research Center, in Hampton, Virginia. He is well known in his field as an aerodynamicist of singular abilities who received the coveted Collier Trophy in 1955 for his discovery and development of the "area rule" theory.

7. The patent in suit relates to a concept and means for solving the problems of shock-induced boundary layer separation and related difficulties, not limited to, but including, the speed of the aircraft. The patent teaches that shock-wave induced boundary layer separation on lifting-type wings can be reduced by the addition of special elongate bodies on the upper surface of the wing, with the result that at high subsonic speeds, and the total drag on the aircraft is reduced by delaying the drag rise associated with transonic flow over the wing surfaces.

8. The Whitcomb patent discloses specifically that the boundary layer separation can be reduced or minimized by placing the specially shaped elongate bodies chordwise along the wing. Such bodies have a forward portion that gradually increases in cross-section, approximately like a cone; the bodies increase in cross-section to a maximum thickness at or near the trailing edge of the wing; and

the aft portions of the bodies extend rearward of the wing trailing edge, gradually tapering from the maximum. The patent teaches that the gradually increasing forward region of the bodies lies at or just ahead of the region of the maximum thickness of the wing so as to gradually decelerate the air velocities and to delay the transition from subsonic flow to supersonic flow, while the remaining portions gradually increase to a maximum at the trailing edge and then gradually decrease so as to alter and gradually reduce the downstream adverse pressure gradients associated with the separation of the boundary layer over the wing.

9. The Whitcomb patent discloses that although the bodies add drag to the airplane at low speeds, one of the most important practical results is that at high speeds, the Mach number at which the drag rapidly increases due to the compressibility drag is "delayed" or raised to a higher value. This means as a practical matter that an airplane with the "anti-shock" bodies can fly faster before the speed-inhibiting drag rise phenomenon occurs.

10. Prior to 1957, Dr. Whitcomb was aware of efforts being made by other researchers to solve the "boundary layer separation" problem associated with flight in the transonic range. Whitcomb had been working at home in his spare time on a solution to this problem and, over a weekend in January 1957, suddenly conceived a solution to the problem. Thereafter, he devised a means for putting his concept into practice. The following Monday Whitcomb disclosed his invention of the patent in suit to Axel T. Mattson, his supervisor at NASA, and subsequently to other co-workers at Langley Field.

11. Subsequently, tests were authorized at the Langley Field wind tunnel by Whitcomb's supervisor, using an available model, to determine the extent of the effectiveness of the bodies disclosed by Whitcomb. In May 1957, Whitcomb prepared an additional patent disclosure and requested that an application for patent be filed at government expense,

agreeing to grant the government an irrevocable, royalty-free license for governmental purpose. The disclosure and request were forwarded on May 13, 1957 by Whitcomb's supervisor to NACA Headquarters for consideration.

12. On about August 3, 1957, Whitcomb was advised for the first time that the government would file a patent application on his invention of the patent in suit.

13. On October 9, 1957, Whitcomb executed a patent application, prepared by the Office of Naval Research, describing the invention of special bodies and the opening paragraph of that application recited that the invention could be used by or for the United States Government, for governmental purposes, without the payment of any royalties. The description of the bodies was essentially the same as Whitcomb's written disclosures in February, the description being amplified by his subsequent May 13, 1957 disclosure and his August 9, 1957 letter making further changes.

14. Following the filing of Whitcomb's patent application, NACA officials determined, after consideration of the circumstances involved in the making of the invention, that Whitcomb was entitled to retain title to his patent application, subject to the irrevocable license already assigned by Whitcomb for governmental purposes. On December 19, 1957, patent representatives of NACA requested concurrence by the Government Patents Board which had final jurisdiction under Executive Order 10096. On August 12, 1958, the Chairman of the Government Patents Board addressed a letter to the Patent Liaison Officer at Langley advising him that the report and supplemental information supplied by NACA had been reviewed pursuant to Executive Order 10096, and had determined that the government was not equitably entitled to an assignment to the entire right, title and interest in and to the invention, and that, "title to the invention should be left in the inventor." This decision was communicated from NASA headquarters to Langley Field on October 29, 1958.

Publications of Whitcomb's Invention and Use of His Disclosures.

15. Based upon the results shown by his first wind tunnel tests, Dr. Whitcomb began preparation of a Research Memorandum to be published by NACA disclosing the usefulness of the invention. Prior to the publication of that Memorandum, in early July 1957, Whitcomb was instructed by his superiors to give an interview to an "Aviation Week" editor to discuss for publication the results of his invention.

16. On July 24, an invitation was also sent out by the Director of NACA to representatives of the military and certain aircraft manufacturers to send representatives to visit Whitcomb to discuss his invention, prior to the general publication of his memorandum. Whitcomb was ordered to disclose his invention to these representatives.

Whitcomb was then visited by representatives from the Air Force, who were interested in improving the performance of military airplanes, and by representatives of the various airframe manufacturers, including Lockheed, McDonnell, Boeing, General Dynamics and Douglas Aircraft.

The *first* such visitor was James G. Wenzel from the Convair division of General Dynamics who met and talked with Dr. Whitcomb on July 30, 1957.

17. At the meeting between Whitcomb and Wenzel, it seems to be agreed that Whitcomb did describe his concept to Wenzel, showed him the data about to be published, and permitted him to trace or copy some of the data. While Wenzel claims that the discussion included the mention of Convair's commercial 880 jet transport program and that Whitcomb was "disappointed" that industry had shown no interest in using his invention of the special bodies, doubt is cast on this version of events by Whitcomb's denial of such discussions, and by the fact, supported by contemporaneous documentation, that Wenzel was the very *first*

person from industry to contact or talk to Whitcomb about his invention. Thus, Whitcomb could not possibly have been "disappointed" because at that time no one else had seen him and the industry did not yet even know about his discovery.

18. After his conference with Whitcomb, Wenzel returned to Convair, San Diego, prepared and distributed copies of his trip report of the meeting, including the data he had copied from Whitcomb's memorandum drafts. To the aerodynamicists at Convair, who had previously been searching for a way of reducing drag rise and obtaining a higher speed, the Whitcomb disclosures were regarded as "an important milestone." Although skeptical at first, they later saw that Whitcomb's data revealed that the drag could be delayed to a higher Mach number, and realized that this represented the "breakthrough" they had been seeking.

19. Immediately after receipt of Whitcomb's disclosures, on August 14, 1957, Convair ordered models to be made for wind tunnel testing of bodies identical to those shown and described in Whitcomb Research Memorandum. A series of tests, on December 10-13, 1957, were completed so that Convair could determine the effects of the bodies on the drag of its jet transport under development. These tests were exhaustive and included data on the effects of the bodies at various speeds (Mach numbers) and at various lift coefficients. The tests results clearly showed Convair that at high subsonic speeds, the bodies delayed the drag rise and had a favorable effect on the speed of the airplane.

20. Whitcomb was next contacted by a Convair representative when he was consulted in early January 1959 by Mr. George Grogan, of the Fort Worth Division of Convair about the B-58 "Hustler" bomber design. During their conversation at Langley Field on January 9, 1959, Whitcomb told Mr. Grogan, an old acquaintance, of his pending

patent application on the anti-shock bodies. Whitcomb invited Grogan to convey this information about his application and the fact that he had title to the application to Convair officials at San Diego where the transport was to be built. Grogan indicated that he would, and this information was communicated to such Convair officials at San Diego almost immediately.

21. On January 5, 1961, Convair was notified by the Manufacturers Aircraft Association of the issuance of Whitcomb's patent in suit. This notification triggered further activity by Convair patent department, which obtained a "file history" of Whitcomb's patent and started a further and even more extensive validity search for further prior patents and publications. In addition, the patent department held many extensive interviews with the engineers and aerodynamicists working on the 990 program to obtain statements from them regarding Whitcomb's patent and the history of the anti-shock bodies. All of this material was added to the growing "Whitcomb File" which was being kept by Convair. At about this time, the word was passed around at Convair that no one should contact Whitcomb about his patent.

22. In January 1962, Convair patent personnel had further interviews with persons in the Engineering Department regarding contacts with Whitcomb. The opinion was recorded that General Dynamics' "present approach" to the matter appeared to be correct. In February 1962, Whitcomb made an unusual trip to San Diego, at the urgent request of Convair, to help them solve certain problems unrelated to the anti-shock bodies, and while there he saw the 990 aircraft for the first time and observed the shaping and location of the bodies on the wing. Following that visit, Whitcomb returned to Langley Field and, shortly thereafter, contacted patent attorneys to ascertain whether the airplane infringed the patent in suit. After consultations with counsel, notice that the 990 was considered an

infringement of Whitcomb's patent was mailed to General Dynamics in May 1962.

23. During the entire period from January 1959, when it first learned of Whitcomb's patent application on the speed bodies, through to 1962, when the 990 airplane was completed, General Dynamics never advised Whitcomb personally of its intention to use his invention in its commercial jet transports, nor did it seek permission or license from Whitcomb to use the invention. It was well known to General Dynamics that NACA allowed its employees to retain private patent rights, and there is no evidence to suggest that at any time during that period did General Dynamics have any belief that it did *not* need a license, or that it already had a license to practice Whitcomb's invention.

General Dynamics' Contract with American Airlines, Inc.

24. In the winter of 1957-1958, the Convair division of General Dynamics opened negotiations with American Airlines for the purchase of a more advanced jet transport which would prove superior in performance to the existing designs by Boeing and Douglas. It was the specific aim of American Airlines to acquire a faster airplane and the speed guarantees were at all times an important part of the negotiations. Very early in the negotiations, General Dynamics proposed the use of anti-shock bodies, based upon Convair's tests of Whitcomb's bodies, to provide the speed increase demand by American Airlines. Convair Report ZD-22-005, a specification dated January 27, 1958, contained a specification for anti-shock bodies to be mounted on the wings to inhibit the formation of shock waves at high speeds. The illustrations of the airplane in this report show one outboard anti-shock body on each wing of the airplane. Throughout this time period, publications of General Dynamics and American Airlines continually

wrote glowingly to the public of the results of the use of the shock bodies and the benefit thereof to air travelers.

25. On July 1, 1958, Convair Division of General Dynamics and American Airlines entered into an agreement for the purchase of twenty-five (25) aircraft. The specifications called for a guarantee maximum cruise speed of 543 knots, plus or minus 2%.

26. On July 1, 1958, the design of the anti-shock bodies for the airplane was not yet final. The design for the anti-shock bodies was completed in December 1958 and the production drawings for the airplane were released in September 1959.

27. After construction of the 990 airplanes by Convair in 1961, it became apparent that the designs of several portions of the aircraft, principally in the engine nacelle pod-plyon arrangement, were faulty and substantially increased the drag of the airplane, thus reducing the speed of the airplane below that guaranteed to American Airlines.

28. In 1961, American Airlines canceled the Purchase Agreement, because of the non-delivery of aircraft according to the contract guarantees. Subsequent to the cancellation, negotiations reopened, looking toward a new contract. The tenor of subsequent negotiations is best shown by Whitcomb Exhibit 95, a memorandum by the Chairman of American Airlines, covering a meeting of the top management of both companies. The memorandum shows that the cruising speed of the 990 was a prime concern of American Airlines, and that if General Dynamics could not guarantee a cruising speed of at least 530 knots, there would be no sale.

29. A new contract for the purchase of the 990 by American Airlines was made in September 1961. American's concern about the cruise speed of the aircraft was reflected in specific contract provisions whereby American would

place into escrow $500,000 of the purchase price of each aircraft, with increments of this amount to be made to Convair as an additional payment, depending upon the cruising speed eventually demonstrated. If the speed demonstrated by Convair was 545 knots, Convair would receive the entire additional $500,000 per airplane, but if the demonstated speeds were less than 535 knots, American could refuse to accept the airplanes.

30. Pursuant to this renegotiated contract, General Dynamics ultimately demonstrated in 1962 a cruising speed of 542 knots for the 990 aircraft and delivered the airplane to American, receiving an additional payment of $400,000 per airplane from American Airlines.

Infringement of Whitcomb's Patent by General Dynamics

31. Each of the 990 of 990A airplanes manufactured by General Dynamics has bodies on the wings which have been designated "anti-shock bodies" and "speed capsules" in various documents and publication[s] originated by American Airlines and General Dynamics. The "anti-shock bodies" or "speed capsules" are substantially identical in configuration on all versions of the 990 and 990A.

32. Each of the Convair 990 and 990A aircraft manufactured by General Dynamics is an airplane having a fuselage and a wing panel extending from each side of the fuselage. The outboard "anti-shock body" or "speed capsule" on each wing panel of the 990 and 990A is an elongate body on the upper surface of the wing panel extending generally chordwise of the wing panel. Each outboard anti-shock body has a forward region of a progressively increasing cross-sectional area approximately the same as that of a cone extending just forward of the wing panel region of maximum thicknes. Each outboard anti-shock body further has a region of maximum cross-section near

the wing panel trailing edge. Each outboard anti-shock body also has a rear tapered portion extending aft of the wing panel trailing edge.

33. Each of the bodies referred to in Finding 32 has a straight axis extending in the flight direction, and also has a circular cross-section. Thus, each outboard anti-shock body corresponds to each feature of claims 1, 2 and 3 of the Whitcomb patent in suit.

34. The anti-shock bodies on the 990 and 990A aircraft were primarily intended by General Dynamics to perform the aerodynamic function of reducing drag of the airplane at high subsonic speeds. The anti-shock bodies were intended by General Dynamics to straighten the air flow over the wing at high speeds, and thus to delay the formation of shock waves over the wing which induce boundary layer separation. The purpose of the anti-shock bodies on the Convair 990 and 990A aircraft is substantially the same as the teachings of the Whitcomb patent in suit. Although the anti-shock bodies also carried fuel, this was only a secondary purpose, and they remained on the airplane as effective aerodynamic anti-shock bodies.

35. The anti-shock bodies on the wings of the Convair 990 and 990A aircraft have a beneficial effect on the drag of the airplane at high subsonic speeds and contribute an increase of at least 10-12 knots to its cruising speed.

Prior art, patents and publications.

Originally, defendant, General Dynamics, had indicated nearly 100 items of "prior art" considered by them between January, 1959 and March, 1968. Only about fifty (50) of these were considered relevant enough to include in the required Notice of Statutory Prior Art filed before trial. Actually, evidence was only presented to fifteen (15) of these items identified as the Küchemann reports (General Dynamics Exhibits 21-25, 40); Russian airplane, TU-104

(General Dynamics Exhibits 49-51); the Hütter "Dopplereiter" report (General Dynamics Exhibits 52 and 52A); 2 U.S. patents (General Dynamics Exhibits 42 and 44); a German patent (General Dynamics Exhibit 42); and 4 NACA Research Memoranda (General Dynamics Exhibits 45-48). Each of these will be commented on separately.

36. Beehereau U.S. Patent 2,074,201, issued in 1937 (General Dynamics Exhibit 42), was recognized as early as April of 1959, by General Dynamics' Patent Department, as having "no relation to Whitcomb's work." This patent refers only to some "bulges" generally attached to the very trailing edge of the wing, to control, according to General Dynamics' witness, Dr. Goethert, an "eddying flow of air" at low speeds, in contrast to the high speed transonic region of flight contemplated in the Whitcomb patent. This reference is not aerodynamically related to the concept developed by Dr. Whitcomb.

37. The Hertel et al., German Patent 932,410, of 1944 (General Dynamics Exhibit 43), bears no relationship to the invention of the Whitcomb patent in suit. It is directed to another patent of Dr. Whitcomb's, "the area rule," not in suit. It was admitted by General Dynamics' expert at trial (Dr. Goethert) that he could find no structure disclosed in this patent which showed a body mounted on the upper surface of an airplane wing with the features characterized by the claims here in suit. This "prior art" patent bears no possible relationship to the "speed body" or "anti-shock body" invention of the patent in suit. Further, there is no evidence that any of the airplanes disclosed in this patent, if built, would actually accomplish the drag reduction objectives of the Whitcomb patent.

38. The Smith U.S. Patent 2,950,879 (General Dynamics Exhibit 44), is directed to a development applicable for *supersonic* flight conditions, rather than transonic flight conditions, and seeks to improve the lifting characteristics

of the air foil, rather than a reduction in the drag characteristics of the airplane. In fact, Dr. Goethert said he would have to "turn the wing over" to find any similarity in the Smith patent and he further admitted that the bodies shown in the Smith patent were "obviously" to aid in control of aileron surfaces, and are distinctly different in nature and in location on the wing from the bodies described in the claims of the Whitcomb patent here in suit. This prior art reference is not aerodynamically related to the concept developed by Dr. Whitcomb.

39. A report authored by Silvers and Spreeman, NACA RM L7K20, dated in 1948 (General Dynamics Exhibit 45), was concerned with an entirely different problem of "interference" between the *lower* surface of the wing and the adjacent fuselage; prescribed bodies, *under* the wing, having a shape quite different from those required by the claims of Whitcomb's patent in suit, and states that such bodies should be located at a different position from that prescribed by Dr. Whitcomb, with "very little" effect on air flow above the wing (Dr. Goethert).

40. The NACA Report authored by Hanson and Dannenburg, of 1948 (General Dynamics Exhibit 46), also describes tests with various blunt-nosed "nacelles" placed at various positions on the wing of a wing tunnel airplane model—but none of these positions, or bodies, corresponds to the location and shape required by Dr. Whitcomb's patent. General Dynamics' expert admitted that the additional nacelles all had "positive" drag coefficient numbers which indicated that the wing bodies proposed in this patent generally added to the drag of the airplane, in contrast to the reduction in such drag achieved by the invention of the patent in suit. Furthermore, the different shape of the bodies in this report produced a "sharp change" in the pressure over the surface of the wing, in contrast to the objective of Whitcomb's patent, which is to obtain a gradual deceleration and change of air pressure. The sharp change of

pressure produced by the nacelles of this report is not only undesirable at low subsonic speeds, but becomes very bad at higher speeds in the transonic region where the boundary layer separation problem sets in. The content of this report is not aerodynamically related to the invention of Whitcomb's patent in suit.

41. The report authored by Silvers, King and Pasteur, NACA RM L51H16, of 1951 (General Dynamics Exhibit 47), shows that the nacelles it describes when added to an airplane would reduce the drag rise Mach number, that is, cause the sharp increase in drag to occur at a lower speed. This is in contrast to the bodies of Dr. Whitcomb's patent in suit which have the effect of delaying or increasing the drag rise Mach number. The report generally tests the nacelles in an "underwing" position, but when it tested such nacelles in an "overwing" location, it reported that this led to the bad effects of "increased nacelle interference drag." In fact, the drag for the overwing placement of the nacelle was always much higher at all speeds tested in the report, and General Dynamics' expert testified that, "these are bad results," and that this "particular type of nacelle is no good" in this report. The evidence also shows that the nacelles are of a different shape from those called for in Dr. Whitcomb's patent. The content of this report is, therefore, also aerodynamically unrelated to the invention of the patent in suit.

42. The Baldwin and Dickey NACA RM A54J19 of 1955 (General Dynamics Exhibit 48), is not directed to problems of transonic flight, but is an attempt to apply certain "area rule" theories to supersonic speeds. Investigations of such supersonic speeds are not relevant to the problems of boundary layer separation involved in the patent in suit because the basic laws of aerodynamics reverse at the speed of sound. Furthermore, while the supersonic region of flight is somewhat theoretically predictable, the transonic region of flight is well established as an unpredictable situa-

tion. While the report shows added bodies or nacelles on the wing of an airplane wind tunnel model, when these bodies were added to the 'area rule" configuration, they produced a higher drag in the subsonic regions of flight. The bodies of this report are "tandem" bodies, part extending forward of the wing and having a "waisted" portion, and were unfavorable because they caused a low flight speed drag which was too large. This report again has no relationship to Dr. Whitcomb's patent in suit.

43. Evidence of four Russian airplanes, the TU-104, the "Badger," the "Bison," and the "Bear" was also offered as "prior art." (General Dynamics Exhibit 49-51). The evidence indicates, however, that while the Russian airplanes were developed by competent aerodynamicists, to achieve as high a speed as possible according to the state of the art at that time, the best the Russian designers were able to achieve was an airplane of much lower speed (100 knots slower) than that of the infringing Convair 990 aircraft. There is no evidence that any of these airplanes incorporated a "wing body" structure in any way similar to the anti-shock bodies of Dr. Whitcomb's invention—the only "protuberances" appearing on the upper surface of the wings of these airplanes was associated, essentially, with a large landing gear housing mounted underneath the wing[s]. The upper protuberances were not established as having any of the features specified in the claims of Whitcomb's patent, and there is no evidence that these protuberances had any effect whatsoever in controlling or solving the boundary layer separation problems.

44. While evidence was introduced (General Dynamics Exhibit 52 and 52a) of certain experiments (Hütter Report) which took place during World War II on the Focke-Wulf FW-190 German fighter airplane, and specifically a modification including a "Doppelreiter" body on the wing thereof, this evidence did not establish that such experimental airplane utilized a structure corresponding to that

defined by the claims of the Whitcomb patent, nor that the German experimental structure was effective to achieve the purposs of Dr. Whitcomb's invention. The micro-file report describing this airplane shows that the "Doppelreiter" body did not have a forward region, just ahead of the maximum thickness of the wing, which had a cross-sectional area increasing approximately the same as a cone, as is required by the claims of Dr. Whitcomb's patent. Exactly the contrary was established by competent and believable evidence, which was unchallenged by the defendant. It is also clear that the "Doppelreiter" added to the drag of this Focke-Wulf airplane, which only flew at speeds of about 260 mph. It was also admitted that the "Doppelreiter" body was not placed upon the airplane for the purpose of suppressing shocks, which is, by contrast, a specific purpose and achievement of the anti-shock bodies of Dr. Whitcomb's patent.

45. The series of Royal Aircraft Establishment Reports (AERO Reports) (General Dynamics Exhibits 11-19) were introduced as evidence of aerodynamic developments in England prior to the Whitcomb invention. None of these reports, however, discloses a body mounted in the mid-semi-span region of the wing of an airplane where the Whitcomb bodies are to be located. Generally, these reports fall into two classifications: one group relating to investigations of interference effects on the *tail* unit of airplanes, and one group relating to interference effects of *wing and fuselage* combinations. None of these reports teaches the Whitcomb concept of adding bodies to the wing semi-span to delay shock-induced drag rise.

46. AERO Report 2908 (General Dynamics Exhibit 11) by Küchmann and Weber is entitled: "The Supersonic Flow Past Swept Wings at Zero Lift Without and With Body." The *"body"* referred to *is* really *only the fuselage* of the airplane, and there is no teaching in this report that one should add bodies to the mid-semi-span of the wing.

The specific objective of this study is to reduce the interference effects between the wing and fuselage, and the method indicated of achieving this is to indent the fuselage in order to straighten the isobars (imaginary lines of equal pressure) on the wings. This straightening of isobars is contrary to the effect of the bodies of the Whitcomb patent.

47. AERO Reports 2109 (General Dynamics Exhibit 15), 2382b (General Dynamics Exhibit 16), 341 (General Dynamics Exhibit 17), all involved Dr. Küchemann, were classified as "secret" during and at all times relevant to being "prior art" in this suit, and accordingly were held inadmissible as (a) prior publication or (b) evidence of prior knowledge, unless it could be shown that Whitcomb had actual knowledge thereof—which General Dynamics has failed to establish. Nevertheless, by way of comment, all of the AERO Reports, including 2296 (General Dynamics Exhibit 12) and 2260 (General Dynamics Exhibit 13) all are concerned only with studies of the *tail unit* of an airplane, specifically, the junction of the fin and tail-plane. None of these reports are concerned with the effect of a boundary layer separation on lifting wings, and therefore not aerodynamically related to the Whitcomb patent. In these reports there is reference to "junction fairings" and "bullet fairings" added to the tail-plane unit. The general conclusion of the reports, however, is that such would have no effect on critical Mach numbers and would be of little use at high speed from the standpoint of drag.

48. AERO Reports 2901 (General Dynamics Exhibit 15), AERO 2832b (General Dynamics Exhibit 16) and AERO 341 (General Dynamics Exhibit 17) were classified documents at all times prior to the filing of Whitcomb's patent application on November 13, 1957. AERO Reports 2382b and AERO 341 were never received at the Technical Library at Langley Field. The WADC Technical Note 56-236 (General Dynamics Exhibits 40 and 57) was a classified

document at all times prior to 1966. There is no evidence that the photographs of the "Gloster Javelin" attached to the King affidavit (General Dynamics Exhibit 40) were ever received within the United States at any time prior to the filing of Whitcomb's patent application on November 13, 1957.

49. The evidence relating to the "Gloster Javelin" indicates that the bodies affixed to the trailing edge of the wing of that airplane were not conceived for the purpose of controlling shock-induced boundary layer separation. In any event, the bodies were located well rearward of the maximum thickness of the wing and there is no evidence that the forward region of these bodies had a conically increasing cross-sectional area. The only contemporaneous report shows that the bodies had no effect on the magnitude or onset of buffet. It was concluded that there was no advantage to the bodies and they were not included in the production airplane.

50. Considering all of the items of prior art relied upon by General Dynamics and American Airlines, no prior patent or publication discloses an elongate body shaped and positioned as specified in claims 1, 2 and 3 of the Whitcomb patent, on the wing panel of an airplane to control shock-induced boundary layer separation, and to reduce drag in the transonic region of flight.

51. None of the prior patents or publications relied upon by General Dynamics and American Airlines anticipate the invention of the Whitcomb patent in suit.

52. The prior patents and publications relied upon by General Dynamics and American Airlines did not make either the concept or the claimed invention of the Whitcomb patent in suit obvious to one of ordinary skill in the art, at any time prior to Whitcomb's invention.

53. There is no evidence of any fraud or other inequitable or bad faith conduct on the part of Dr. Whitcomb in either

the acquisition of his patent rights or in his contacts with General Dynamics. Dr. Whitcomb is in no way estopped from enforcing the patent in suit against either General Dynamics Corporation or American Airlines, Inc.

* * * * * * * * * *

Conclusions of Law

1. This Court has jurisdiction over the subject matter of the controversy which is the infringement of U.S. Patent 2,967,030 to Richard T. Whitcomb, has jurisdiction over the persons of each of the parties, and venue in this district is proper. 28 U.S.C. §§ 1338(a), 1391 and 1400(b).

2. Richard T. Whitcomb is the owner of the entire right, title and interest in and to United States Patent 2,967,030, subject only to an irrevocable royalty-free license granted by him to the United States Government, for governmental purposes, pursuant to 35 U.S.C. § 266. There is no proof of fraud, bad faith, or any other inequitable conduct on the part of Richard T. Whitcomb which would estop him from enforcing patent 2,967,030, against either General Dynamics Corporation or American Airlines, Inc.

3. The Whitcomb patent, 2,967,030, was duly and regularly issued by the United States Patent Office.

4. The Whitcomb patent, 2,967,030, is not invalid for lack of novelty under 35 U.S.C. § 102.

5. The Whitcomb patent, 2,967,030, is not invalid for obviousness under 35 U.S.C. § 103.

6. Claims 1, 2 and 3 of the Whitcomb patent, 2,967,030, have been infringed by the manufacture and sale by General Dynamics of the Convair 990 and 990A aircraft. 35 U.S.C. § 271.

7. Richard T. Whitcomb is entitled to an award of damages for infringement of United States Patent, 2,967,030.

8. Damages will be the subject of a separate inquiry. The parties will hold an initial conference in the office of counsel for the plaintiff on Friday, February 27, 1970, at 11:00 A.M., towards agreeing upon suitable alternate dates for such hearing.

9. Counsel for the plaintiff will prepare an appropriate order in keeping with the conclusions herein expressed and making reference to this Memorandum.

JOHN A. MACKENZIE
United States District Judge

Norfolk, Virginia
February 12, 1970

A. 24

Filed Feb. 24, 1970

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF VIRGINIA
NEWPORT NEWS DIVISION

CIVIL ACTION No. 1174

RICHARD T. WHITCOMB, *Plaintiff*,

v.

AMERICAN AIRLINES, INC., *Defendant*.

and

CIVIL ACTION No. 1133
GENERAL DYNAMICS CORPORATION, *Plaintiff*,

v.

RICHARD T. WHITCOMB, *Defendant*.

Order

These causes having come on for trial before this Court, and the trial having been completed, and the Court having considered briefs and proposed Findings of Fact and Conclusions of Law by both parties, and having heard arguments of counsel for both parties, and the Court having heard and considered all of the evidence adduced and being fully advised in the premises and having entered its Memorandum opinion, including the Findings of Fact and Conclusions of Law of this Court, in these causes on February 12, 1970, it is hereby

ORDERED, ADJUDGED AND DECREED as follows:

1. United States Patent 2,967,030 is good and valid in fact and in law.

2. The party Richard T. Whitcomb is entitled to an award of damages for the infringement of the valid United

States Patent 2,967,030 by General Dynamics Corporation in No. 1133, and American Airlines, Inc. in No. 1174.

3. The Complaint by General Dynamics Corporation in No. 1133 and the Counterclaim by American Airlines, Inc. in No. 1174 are hereby dismissed with prejudice.

4. This Court retains jurisdiction of these Actions for further consideration of the award of damages and any other relief to which the party Richard T. Whitcomb is entitled.

DONE AND SO ORDERED at Norfolk, Virginia, this 24th day of February, 1970.

JOHN A. MACKENZIE
John A. MacKenzie
United States District Judge

A True Copy, Teste:
W. FARLEY POWERS, JR., *Clerk*

By G. R. OLD
Deputy Clerk

UNITED STATES COURT OF APPEALS
FOR THE FOURTH CIRCUIT

No. 14,629

GENERAL DYNAMICS CORPORATION, and
AMERICAN AIRLINES, INC., *Appellants,*

v.

RICHARD T. WHITCOMB, *Appellee.*

Appeal from the United States District Court for the Eastern District of Virginia, at Newport News.

John A. MacKenzie, District Judge.

(Argued December 8, 1970 Decided June 15, 1971.)

Before SOBELOFF,* WINTER and CRAVEN, *Circuit Judges.*

William K. Kerr (Albert E. Fey, and Fish & Neave; Jack E. Greer, and Williams, Worrell, Kelly & Worthington on brief) for Appellant, and Carl G. Love (William K. West, Jr., Donald J. Bird, and Cushman, Darby & Cushman; Edward L. Breeden, III, and Breeden, Howard & MacMillan on brief) for Appellee.

SOBELOFF, Senior Circuit Judge:

The patent which is the subject of this litigation pertains to a device in the field of aerodynamics. Richard T. Whitcomb is the holder of United States Letters Patent No. 2,967,030 for a "Boundary-Layer Control Means for Lifting Wings." General Dynamics Corporation brought suit against Whitcomb for a declaratory judgment that his patent is invalid and not infringed by General Dynamics. Whitcomb counterclaimed, seeking damages for infringement. A second suit was instituted by Whitcomb against

* Judge Sobeloff attained the status of Senior Circuit Judge on December 31, 1970.

American Airlines, Inc., for infringement of the same patent. American counterclaimed for a declaratory judgment of the patent's invalidity and its noninfringement.

American's asserted liability stems from its purchase and utilization of General Dynamics' Convair 990 aircraft. The issues raised by the two law suits are identical and they were accordingly consolidated for trial. The District Court found the patent valid and infringed and held both General Dynamics and American Airlines liable for an award of damages to Whitcomb. We reverse upon our conclusion that the General Dynamics plane does not infringe the patent.

The mechanical devices at issue in this case, sometimes referred to as "aerodynamic antishock bodies" or "speed capsules," are intended to diminish the adverse effects of an airflow phenomenon known to aerodynamicists as boundary layer separation. During flight, the air which is displaced by an airplaine wing and forced to flow over the wing's upper surface actually moves at a faster speed than the plane itself. Thus, if an airplane is traveling at transonic speeds, i.e., speeds below but near the speed of sound, a portion of the airflow over the wing will be moving at speeds equal to or greater than the speed of sound.

At the point where the air velocity drops from supersonic to subsonic speed, a sharp pressure change or "shock wave" occurs which causes the layer of air immediately adjacent to the wing to separate and lift up from the wing—the condition known as boundary layer separation. As a result, the smooth airflow over the wing deteriorates into a very turbulent flow which adds substantially to the drag on the wing. Once a plane reaches speeds in this transonic range, small increments of additional speed create large increments of additional drag. This drag rise phenomenon acts as a speed barrier preventing a plane from further accelerating without substantial expenditure of power.

The patentee has been employed by the National Advisory Committee for Aeronautics (NACA) since 1943.[1] Prior to 1957 he was aware of efforts being made to prevent boundary layer separation or at least increase the critical speed at which the drag rise phenomenon begins to occur. In January 1957, working at home on his own time, Whitcomb conceived the idea of adding "antishock bodies" to the wings to reduce boundary layer separation.

The Whitcomb antishock body, shaped rather like a slender, elongated football, though it is considerably larger,[2] is situated on top of the wing. It extends just forward of the thickest part of the wing, with the thickest part of the antishock body located near the trailing edge of the wing. It was Whitcomb's theory that such bodies, by decelerating the airflow over the wing, would enable a plane to reach higher speeds before experiencing substantial drag rise. Subsequent wind tunnel tests confirmed that the antishock bodies smooth the flow of boundary layer air at transonic speeds, and that a wing without antishock bodies experiences drag rise at a lower speed than the same wing with the bodies added. On January 3, 1961, U.S. Letters Patent No. 2,967,030 were issued to Whitcomb for his invention.

Each General Dynamics Convair 990 employs four wing bodies very similar to Whitcomb's. He alleges that the two outboard antishock bodies are so similar as to infringe his patent. On appeal from the District Court's judgment in Whitcomb's favor, General Dynamics and American Air-

---

[1] In 1958 the title of NACA was changed to the National Aeronautics and Space Administration. Because the old name was still in effect when Whitcomb conceived his invention in 1957, it will be used throughout this opinion for the sake of consistency.

[2] On the Convair 990 the two outboard antishock bodies which are alleged to infringe Dr. Whitcomb's patent are each over 24 feet long. The four bodies on the 990, which serve a secondary function as fuel tanks, hold a total of 1136 gallons of fuel.

lines raise four major contentions: (1) that title to the patent should have vested in the Government, (2) that the patent is invalid because obvious in light of the prior art, (3) that they have not infringed the patent, and (4) that Whitcomb by his failure promptly to assert his ownership of the invention, has granted General Dynamics an implied license to utilize his patent. Because we hold that the Convair 990 wing bodies do not infringe the patent, we do not reach the other three issues.

II.

The issue of infringement turns on the wording of claim 1 of Whitcomb's patent:

> 1. In an airplane, a fuselage, a wing panel extending from said fuselage, and an elongate body on the upper surface of said wing panel and extending generally chordwise thereof, said elongate body having a forward region of a progressively increasing cross-sectional area approximately the same as that of a cone and *extending just forward of the wing panel region of maximum thickness*, said elongate body further having a region of maximum cross-section near the wing panel trailing edge, and a rear tapered portion extending aft of the wing panel trailing edge. (Emphasis added.)

In contrast to the portion of claim 1 emphasized above, the challenged General Dyanamics wing bodies extend four feet forward of the region of maximum wing thickness—53% of the distance from that region to the leading edge of the wing.

The District Court found that the General Dynamics wing bodies do extend "just forward" of the wing panel region of maximum thickness. We hold that finding to be clearly erroneous. If we are to give any substantive content to

the phrase "just forward" as distinct from any other type of "forward," it must mean "slightly forward" or "barely forward" of the region of maximum thickness. In our view no permissible reading of the phrase "just forward" can encompass the extension of wing bodies four feet forward; the General Dynamics wing bodies extend too far toward the leading edge of the wing to fit the explicit words of the patent.

Whitcomb attempts to escape the plain and unartificial reading of the patent by arguing that his invention has a nose of some rearward dimension. This entire nose is allegedly situated "just forward" of the region of maximum thickness and therefore the "apex" of the nose may be situated well forward of that region. Regardless of whether the word "nose," more than the word "apex," carries some connotation of a distinguishable forward section, we do not construe claim 1 to suggest that the forward region of the patented body may extend as much as four feet forward of the wing panel region of maximum thickness. We think it more reasonable to read claim 1 as describing a forward region that extends *to* just forward of the wing panel region of maximum thickness and no farther.

This leaves us the question whether the General Dynamics outboard antishock bodies are sufficiently similar to the patented invention to fall within the doctrine of equivalents. The essence of the doctrine is that "if two devices do the same work in substantially the same way, and accomplish substantially the same result, they are the same even though they differ in name, form, or shape." *Graver Tank & Mfg. Co.* v. *Linde Air Products Co.*, 339 U.S. 605, 608 (1950), quoting *Machine Co.* v. *Murphy*, 97 U.S. 120, 125 (1877).

In applying the doctrine of equivalents, two underlying principles must be kept in mind. First, as the *Graver Tank* case emphasizes, the primary purpose of the doctrine is to

prevent fraudulent evasion of the scope of a patent by means of "unimportant and insubstantial changes and substitutions in the patent which, though adding nothing, would be enough to take the copied matter outside the claim, and hence outside the reach of the law." 339 U.S. at 607. Second, differences in form and shape may weigh importantly in the balance "where form is of the essence of the invention." *Machine Co.* v. *Murphy*, 97 U.S. at 125.

The record in this case establishes that wing bodies similar to the outboard bodies on the General Dynamics planes deal more successfully with the boundary layer separation problem than bodies fitting the precise description of Whitcomb's claim 1. Indeed, Whitcomb himself, subsequent to submitting his patent application, tested various wing bodies differing from the original bodies disclosed by his patent. A NACA technical report prepared by him and submitted in evidence at trial compares the original Whitcomb bodies, which extended forward only 4% of the distance from the region of maximum wing thickness to the wing's leading edge, with a wing body extending forward 64% of that distance. At trial Whitcomb admitted that his investigations and report establish that a wing body which extends to the farther forward position is more effective than his original wing bodies.

Because this is a case where form and shape are of the essence of the invention, and General Dynamic's alteration does add to the effectiveness of the device, it cannot be considered a mere evasion of the patent. We hold, therefore, that there is no infringement either under the literal terms of the patent or under the doctrine of equivalents.

Reversed.

A. 32

Filed July 14, 1971

UNITED STATES COURT OF APPEALS
FOR THE FOURTH CIRCUIT

No. 14,629

GENERAL DYNAMICS CORPORATION, and
AMERICAN AIRLINES, INC., *Appellants,*

v.

RICHARD T. WHITCOMB, *Appellee.*

Order

Upon careful consideration of the Motion for Rehearing, and with the concurrence of Judges Winter and Craven, no member of the court having requested en banc reconsideration of the case, the Motion for Rehearing is hereby denied.

SIMON E. SOBELOFF
United States Circuit Judge

A True Copy, Teste:
SAMUEL W. PHILLIPS, *Clerk*
By DIANE HUDSON
Deputy Clerk

Whitcomb Exhibit 4
Whitcomb's Patent U. S. 2,967,030

Jan. 3, 1961 R. T. WHITCOMB 2,967,030

BOUNDARY-LAYER CONTROL MEANS FOR LIFTING WINGS

Filed Nov. 13, 1957 2 Sheets-Sheet 1

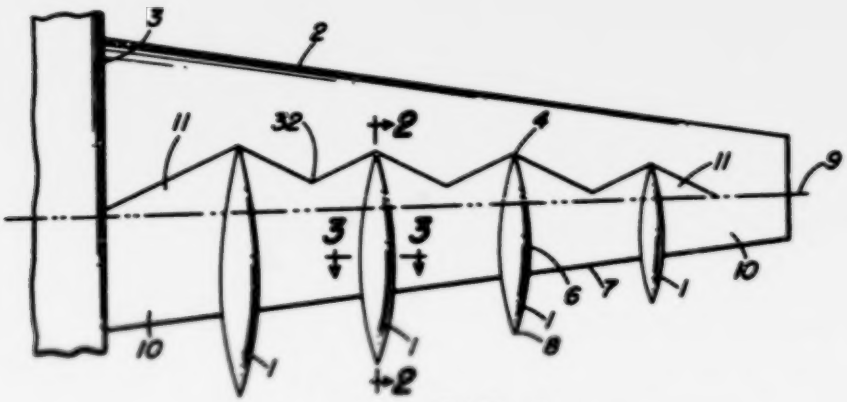

FIG. 1

FIG. 2

FIG. 3

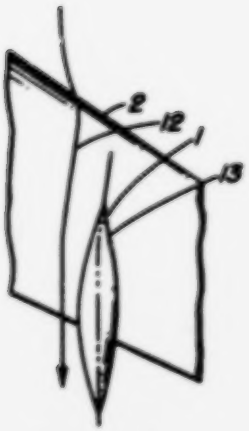

FIG. 4

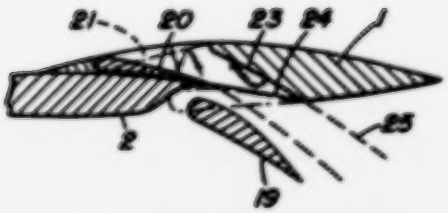

FIG. 5

INVENTOR
RICHARD T. WHITCOMB

BY R. J. Tompkins
ATTORNEYS

Jan. 3, 1961 R. T. WHITCOMB 2,967,030

BOUNDARY-LAYER CONTROL MEANS FOR LIFTING WINGS

Filed Nov. 13, 1957 2 Sheets-Sheet 2

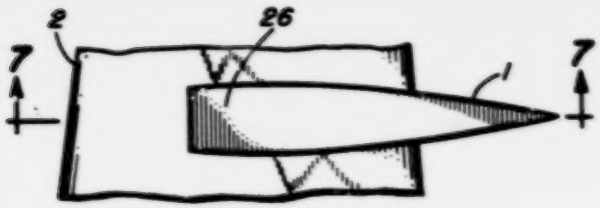

FIG. 6

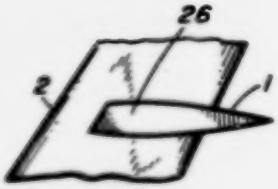

FIG. 10

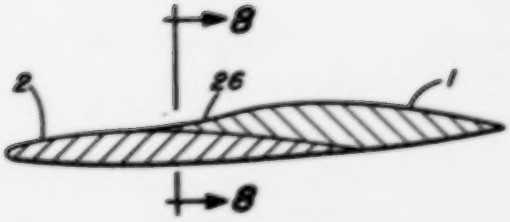

FIG. 7

FIG. 8

FIG. 9

INVENTOR
RICHARD T. WHITCOMB

BY R. I. Tompkins
ATTORNEYS

United States Patent Office

2,967,030
Patented Jan. 3, 1961

2,967,030

BOUNDARY-LAYER CONTROL MEANS FOR LIFTING WINGS

Richard T. Whitcomb, 63C Elizabeth Road, Hampton, Va.

Filed Nov. 13, 1957, Ser. No. 696,297

13 Claims. (Cl. 244—41)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an aerodynamic configuration to reduce boundary-layer separation on the upper surface of a wing, or airfoil, near the speed of sound, and more particularly to an aircraft having bodies on the wing upper surface to delay boundary-layer separation.

When the speed of an airplane with a lifting wing approaches the speed of sound, boundary-layer separation usually develops on the upper surface of the wing. This separation, caused by a shock wave above the wing, results in substantial increases in drag, buffeting, stability problems, and other adverse aerodynamic effects. It is an object of the present invention to reduce the magnitude of this boundary-layer separation and its adverse effects through the addition of a group of special bodies on the wing.

The added bodies are primarily on top of the wing with the noses near or just ahead of the maximum thicknesses of the local wing sections, the maximum cross sections near the trailing edge of the wing, and the aft portions extending downstream of the trailing edge. The forward portions of these bodies decelerate the supersonic flow ahead of the shock wave with a resulting decrease of the strength of the shock and the associated boundary-layer separation. Also, the curvatures of the middle portions of the bodies reduce the adverse positive pressure gradient downstream of the shock wave which further reduces boundary-layer separation. The addition of such bodies to the wing, of course, results in adverse increases in the skin-friction drag and weight of the airplane. However, with the arrangement of the bodies to be described, at high subsonic speeds the favorable effect of the bodies on boundary-layer separation will considerably outweigh these adverse effects.

The objective of this invention is also accomplished by shaping the fuselage as described in my copending application, Serial No. 606,176, filed 24 August 1956, now U.S. Patent No. 2,874,922, issued 24 February, 1959. However, the present invention provides greater effectiveness since the major part of its favorable action is concentrated closer to the locality of most severe separation. The objective of the present invention is also accomplished with bodies added to the wing panels, which extend ahead of the leading edge and behind the trailing edge of the wing and are indented in the region of the wing. However, adding such bodies results in significant added skin friction and weight and flow interference near the wing leading edge. The adverse effects of these bodies are usually considerably more important than the favorable effect of the bodies on boundary-layer separation associated with the shock wave. These adverse effects are greatly lessened with the bodies described herein.

The invention is described by means of the following figures:

Fig. 1 is a partial plan view of an airplane with a representative embodiment of the present invention.

Fig. 2 is a cross-sectional view taken on line 2—2 of Figure 1.

Fig. 3 is a cross-sectional view taken on the line 3—3 of Figure 1.

Fig. 4 is a partial plan view of a swept back wing with an improved embodiment of the present invention.

Fig. 5 is a sectional side view of a further improvement of the invention for use with a wing trailing-edge flap.

Fig. 6 is a partial plan view of a wing with an additional improvement of the invention.

Fig. 7 is a cross-sectional view taken along line 7—7 of Fig. 6.

Fig. 8 is a cross-sectional view taken along 8—8 of Fig. 7.

Fig. 9 is a side view of a special fuselage preferably used with the present invention.

Fig. 10 is a partial plan view of a swept back wing with an alternative embodiment of the additional improvement shown in Fig. 6.

For the representative embodiment of the invention shown in Figures 1 and 2, relatively small bodies 1 are placed on the upper surface of the wing panel 2 which extends from the fuselage shown partially at 3. The noses 4 of the bodies 1 are near or just ahead of the maximum thicknesses 5 of the local wing sections; the maximum cross sections 6 are near the trailing edge 7 of the wing; and the aft portions 8 extend downstream of the trailing edge. The noses are usually at least one quarter of the local chord length rearward of the leading edge. For the greatest effectiveness, the longitudinal development of cross-sectional area, or rearwardly progressive variation in cross-sectional area, for roughly the forward 20 percent of the body lengths are approximately the same as for a cone. The ratio of length to width for the bodies is moderate and the longitudinal contours are smooth. The cross sections of the bodies may be circular as shown in Figure 3 or may have other shapes. One such alternate shape is described later. The bodies are most effective if located roughly one-half to one wing chord length apart as shown in Figure 1.

Flow surveys have indicated that for a usual wing, such as shown in Figure 1, with a normal amount of lift, the initial shock wave usually forms above the upper surface in the vicinity of shock line 9. This shock wave causes boundary-layer separation in the region 10 which lies between line 9 and the wing trailing edge. The shock wave is associated with the presence of a supersonic flow ahead of the shock, the strength of the shock depending on the magnitude of the supersonic velocities. The forward portion of the bodies 1 decelerates the supersonic flow gradually in the approximate region 11, resulting in a decrease in the strength of the shock 9 with a resulting decrease in the severity of separation in region 10. In addition, the severity of boundary-layer separation caused by the shock wave is greatly increased by a gradient of increasing pressure downstream from the shock 9. The curvatures of the midregion of the bodies 1 produce steamwise gradients of decreasing pressure downstream of the shock which partially counteract the adverse increasing gradient associated with the wing in this region. Thus, they result in further reduction of separation in the region 10. The adverse gradients of increasing pressure associated with the aft portions of the added bodies are primarily downstream of the trailing edge of the wing, and thus, have little effect on the separation on the wing.

Whitcomb Exhibit 4
Whitcomb's Patent U. S. 2,967,030

For a lifting sweptback wing the general air flow above the wing moves roughly as shown at 12 of Figure 4, with a slight inward inclination along the forward region and a turn outward above the aft region. Impingement of this laterally directed flow on added bodies with axes aligned with the flight directions, such as shown in Figure 1, causes significant adverse disturbances of the air flow in the vicinities of the bodies which result in local increases of boundary-layer separation. These local disturbances and the associated boundary-layer separation are markedly reduced by shaping the axes of the bodies so that they are roughly aligned with the air flow, as shown at 13 in Figure 4.

The favorable effects described would be accomplished by bodies which have considerable cross-sectional area below the wing. However, additions to the bodies below the wing would add little to the effectiveness as described but would add considerably to the skin-friction drag and weight of the bodies.

The added bodies may be modified, as shown in Figure 5, to provide an improvement in the effectiveness of a wing trailing-edge flap, such as shown at 19, in producing the highest possible lift increment. The modification consists primarily of a flap 20 which moves inside the body 1 between the full line position shown and the dotted line position 21, a ramp 23 inside the body and an opening 24 in the portion of the bottom of the body normally adjacent to the upper surface of the wing flap 19. The inner flap 20 is normally in the dotted line position 21. When the wing flap 19 is deflected downward to the full line position, to provide an increase in lift, the inner flap is also moved from its upper position 21 to the lower full line position. The surfaces of the inner flap and the ramp 23 then divert a stream of air 25 through the opening 24 over the upper surface of the wing flap 19. This stream of air, by reducing the adverse pressure gradients on the wing flap, results in a reduction of the tendency for boundary-layer separation on this flap. Since the maximum lift increment produced by the flap is normally limited by such boundary-layer separation, the stream of air 25 provides an increase in this maximum lift increment.

The effectiveness of the added bodies in reducing boundary-layer separation is improved by the special shaping of the forward portions 26 of the bodies shown in Figures 6, 7 and 8. The cross sections of the bodies are spread spanwise in these regions so that the forward portions of the bodies form wedges with gradually increasing thickness as shown in Figure 7. The contours of the bodies fair smoothly from this wedge to a cross-sectional shape roughly the same as that shown in Figure 1 near the wing trailing edge. When used with a sweptback wing, the leading edge of the wedge is obliquely inclined at approximately the angle of the wing sweep, as shown in Fig. 10. The deceleration disturbances produced by the noses of adjacent bodies intersect between the bodies as shown at 32 in Figure 1. These disturbances augment one another in these regions causing relatively large increases of pressure. With the noses of the bodies pointed as shown in Figure 1, the streamwise rates of increase of pressure in these local regions is sufficiently great to cause boundary-layer separation for many speed and lift conditions. The rates of increase of pressure and the associated separation in these regions are significantly reduced when the noses of the bodies are wedge shaped as shown in Figures 6, 7, and 8.

The value of the bodies added on the wing is significantly improved when these bodies are used in combination with a fuselage shaped as described in my said Patent No. 2,874,922. Such fuselage shapes result in airplanes in which the cross-sectional area in planes generally perpendicular to the longitudinal axis has only a substantially decreasing rate of change from near the nose until the rate of change is zero and has only a substantially negative increasing rate of change rearward of

the zero rate of change point. A side view of an airplane incorporating a fuselage with the special version of such a shape, described in my co-pending application Serial No. 683,431, filed September 11, 1957, now U.S. Patent No. 2,898,059, issued August 4, 1959, entitled, "Fuselage Shaping to Reduce the Strength of the Initial Shock Wave on Lifting Airplane Wings," is shown in Figure 9. The top of the fuselage 27 is contoured longitudinally with a concave curvature 29 in the vicinity of the leading edge of the wing-fuselage juncture 28, a downward slope 30 in the region of the forward portion of the juncture, a concave curvature 31 in the vicinity of the middle region of the juncture, and a longitudinally extending region of substantially constant cross-sectional area downstream of curvature 31. One of the important practical results of adding the bodies to the wing is that the Mach number at which a significant increase in drag occurs is delayed. It has been found experimentally that the delay associated with the bodies is increased significantly when the bodies are utilized in combination with a fuselage shaped as shown in Figure 9. Further, it has been determined experimentally that the adverse drag increment at lower speeds caused by the bodies is substantially reduced when the fuselage is shaped as shown.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

In the claims:

1. In an airplane, a fuselage, a wing panel extending from said fuselage, and an elongate body on the upper surface of said wing panel and extending generally chordwise thereof, said elongate body having a forward region of a progressively increasing cross-sectional area approximately the same as that of a cone and extending just forward of the wing panel region of maximum thickness, said elongate body further having a region of maximum cross section near the wing panel trailing edge, and a rear tapered portion extending aft of the wing panel trailing edge.

2. The apparatus of claim 1, said body being circular in cross section.

3. The apparatus of claim 1, said body having a straight axis extending in the flight direction.

4. The apparatus of claim 1, said body having an axis in approximate alignment with the airflow.

5. In an airplane, a fuselage, a wing panel extending from said fuselage, and an elongate body on the upper surface of said wing panel and extending generally chordwise thereof, said elongate body having a nose generally wedge-shaped in longitudinal cross section tapering to a minimum thickness just forward of the wing panel region of maximum thickness and being smoothly faired to a region of substantially circular cross-section, the maximum region of said substantially circular cross section being near the wing panel trailing edge, and a rear tapered portion extending aft of the wing panel trailing edge.

6. In an airplane, a fuselage, a wing panel extending from said fuselage, said wing panel having a trailing edge flap, an elongate body on the upper surface of said wing panel and extending rearwardly of the wing trailing edge, a slot extending generally downwardly and rearwardly through said body from the upper surface to the lower surface thereof, and a member in the upper part of said body movable from a slot intake closing position to a slot intake opening position, said flap lying in closing relationship to the outlet of said slot when in the retracted position.

7. In combination with an airfoil, at least one elongate closed body on the upper surface of said airfoil aligned with the direction of air flow over said airfoil, the nose of said body being located just ahead of the region of maximum thickness of said airfoil, the forward region of said body having a progressively increasing cross-sec-

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tional area from said nose to a maximum cross-sectional region substantially at the trailing extremity of said airfoil, and the after region of said body tapering to a terminus extending aft of said trailing extremity.

8. The combination of claim 7, wherein the nose and terminus of said body comprise apexes.

9. The combination of claim 7 wherein said body extends generally chordwise of said airfoil.

10. The combination of claim 7 wherein the forward region of said body is of a substantially conical configuration.

11. The combination of claim 7 wherein the separation distance between more than one of said bodies is approximately between one half and one chord of said airfoil.

12. The combination of claim 7 wherein the nose of said body is substantially wedge shaped.

13. The combination of claim 12 wherein the leading edge of said wedge shaped body nose is obliquely inclined at approximately the angle of sweep of said airfoil.

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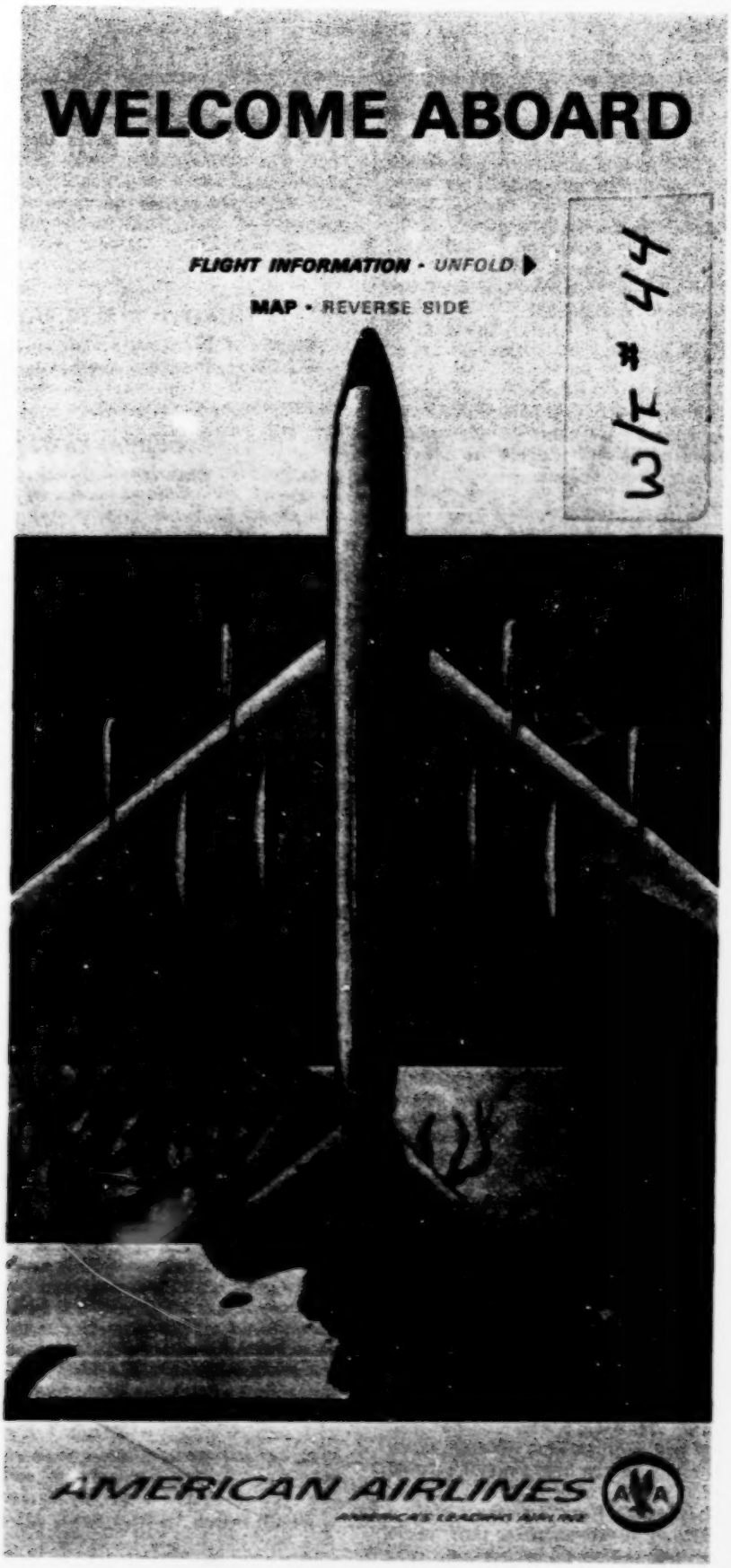
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